

Innovative Approach to Cost Benefit Analysis of Granular Roads

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OVERALL GOAL AND OBJECTIVES

GOAL:

- Evaluation of the cost effectiveness of granular materials based on material characteristics and performance

Objectives:

1. Identify benefits associated with different types of aggregate materials based on their long-term performance
2. Investigate the economic performance of granular roads constructed with the different materials
3. Develop methodology to evaluate the cost-effectiveness of granular materials from different sources

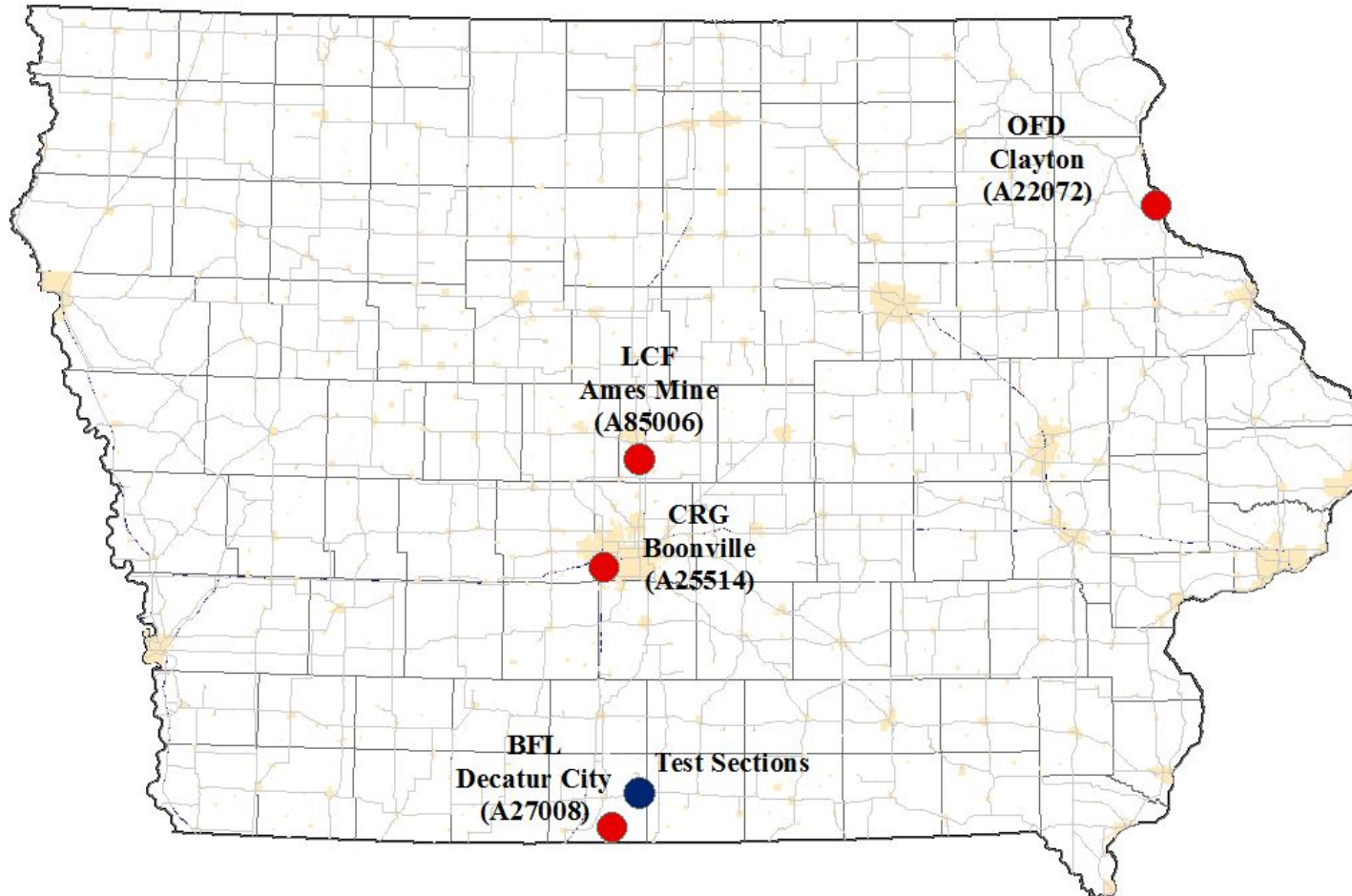
MOTIVATION

1. More than 60% of the road network in the State of Iowa
2. Annual maintenance costs \$270 million
3. Lack of high quality aggregate sources
4. Resilient and sustainable infrastructure

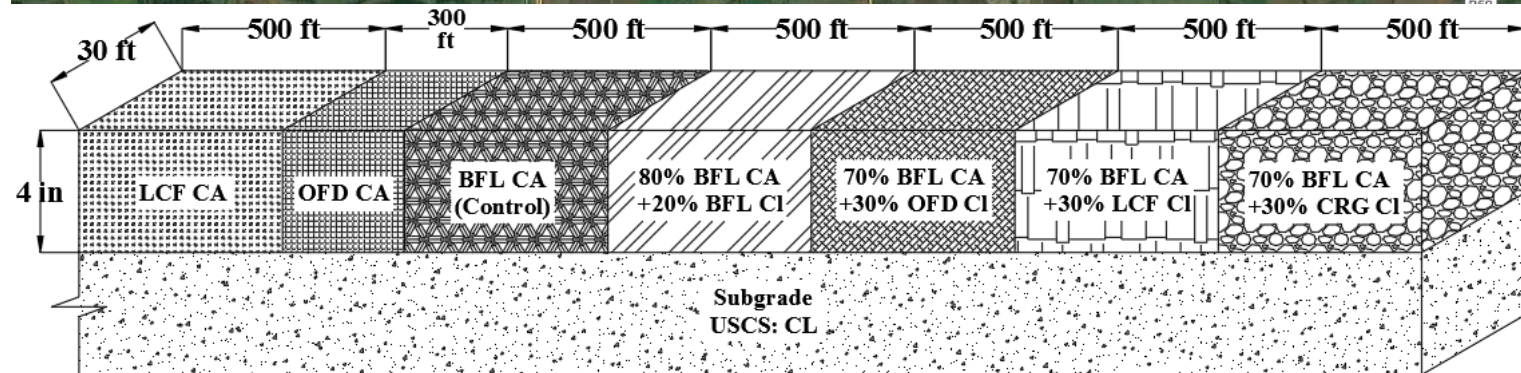
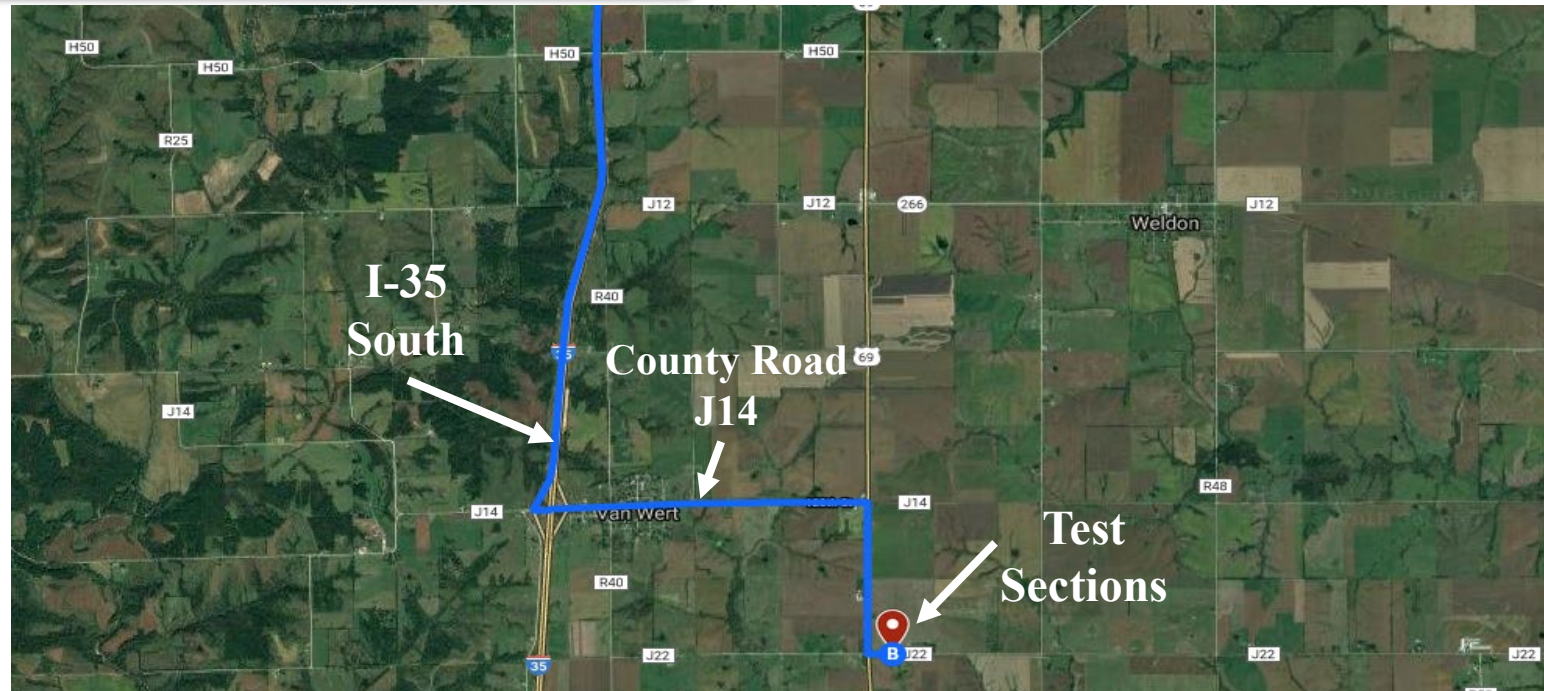


Same location same freeze thaw
cycles

AGGREGATE SOURCES



SITE LOCATION



TEST SECTIONS: September 2016



LCF Class A



OFD Class A



BFL Class A - Control



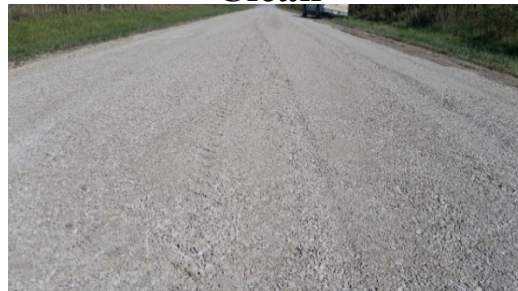
**80% BFL Class A+20% BFL
Clean**



**70% BFL Class A+30% OFD
Clean**



**70% BFL Class A+30% LCF
Clean**



70% BFL Class A+30% CRG Clean

AGGREGATE PROPERTIES

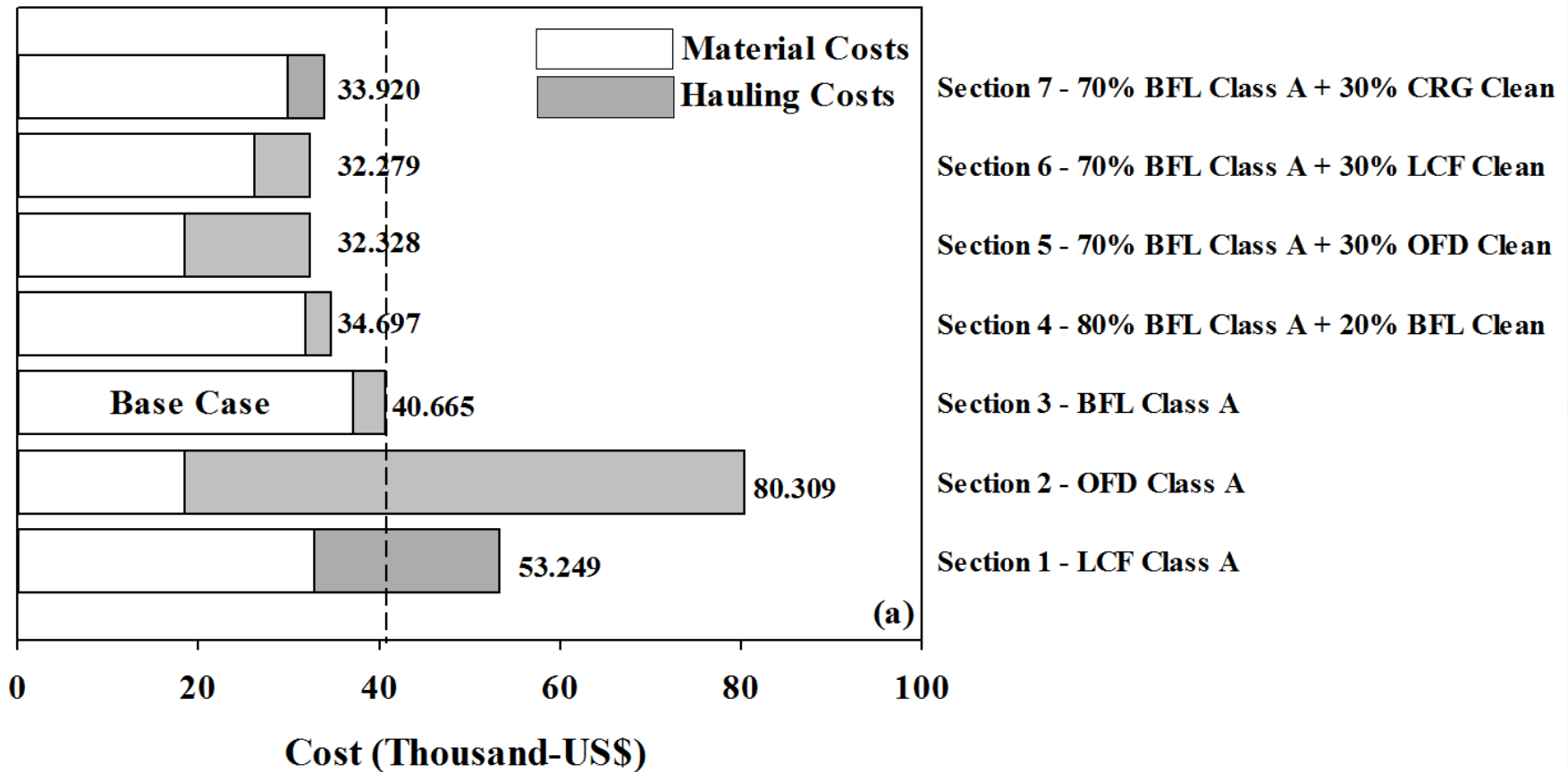
Parameter	LCF Class A	OFD Class A	BFL Class A	80% BFL Class A + 20% BFL Clean	70% BFL Class A + 30% OFD Clean	70% BFL Class A + 30% LCF Clean	70% BFL Class A + 30% CRG Clean	Subgrade
Particle-size analysis results (ASTM D422-03)								
Gravel Content (%) (>4.75mm)	46	54	61	79	72	65	71	12
Sand Content (%) (4.75mm – 75µm)	45	37	24	13	18	23	19	24
Silt Content (%) (75µm – 2µm)	8	8	14	8	8	11	9	53
Clay Content (%) (< 2µm)	1	1.3	2	0	2	0	0	11
Coefficient of Uniformity, C_u	48	91	185	25	111	154	103	0
Coefficient of Curvature, C_c	7	2	17	5	19	17	19	7
Atterberg limits test results (ASTM D4318-10e1)								
Liquid limit (%)	15	NA	20	20	19	17	19	31
Plasticity Index	1	NA	4	5	4	3	5	12
AASHTO and USCS soil classification (ASTM D2487-11 & D3282-09)								
AASHTO	A-1-a	A-1-a	A-1-a	A-1-a	A-1-a	A-1-a	A-1-a	A-6
USCS group symbol	GW	GW	GW	GW	GW	GW	GW	CL
USCS group name	Well-Graded Gravel	Well-Graded Gravel	Well-Graded Gravel	Well-Graded Gravel	Well-Graded Gravel	Well-Graded Gravel	Well-Graded Gravel	Sandy Lean Clay

CONSTRUCTION PROCEDURE

Step 1	Hauling from quarry to piles	Truck
Step 2	Scraping the existing surface	Motor Grader
Step 3	Hauling from pile to site	Loader and Truck
Step 4	Blading	Motor Grader
Step 5	Compacting	Drum Roller

Sections	Labor (hr)	Grader (hr)	Tandem Dump (hr)	Bottom Dump (hr)	Drum Roller (hr)
LCF Class A	66	16	21	7	5
OFD Class A	46	11	15	5	4
BFL Class A – Control Section	66	16	21	7	5
80% BFL Class A + 20% BFL Clean	66	16	21	7	5
70% BFL Class A + 30% OFD Clean	66	16	21	7	5
70% BFL Class A + 30% LCF Clean	66	16	21	7	5
70% BFL Class A + 30% CRG Clean	66	16	21	7	5

CONSTRUCTION COSTS

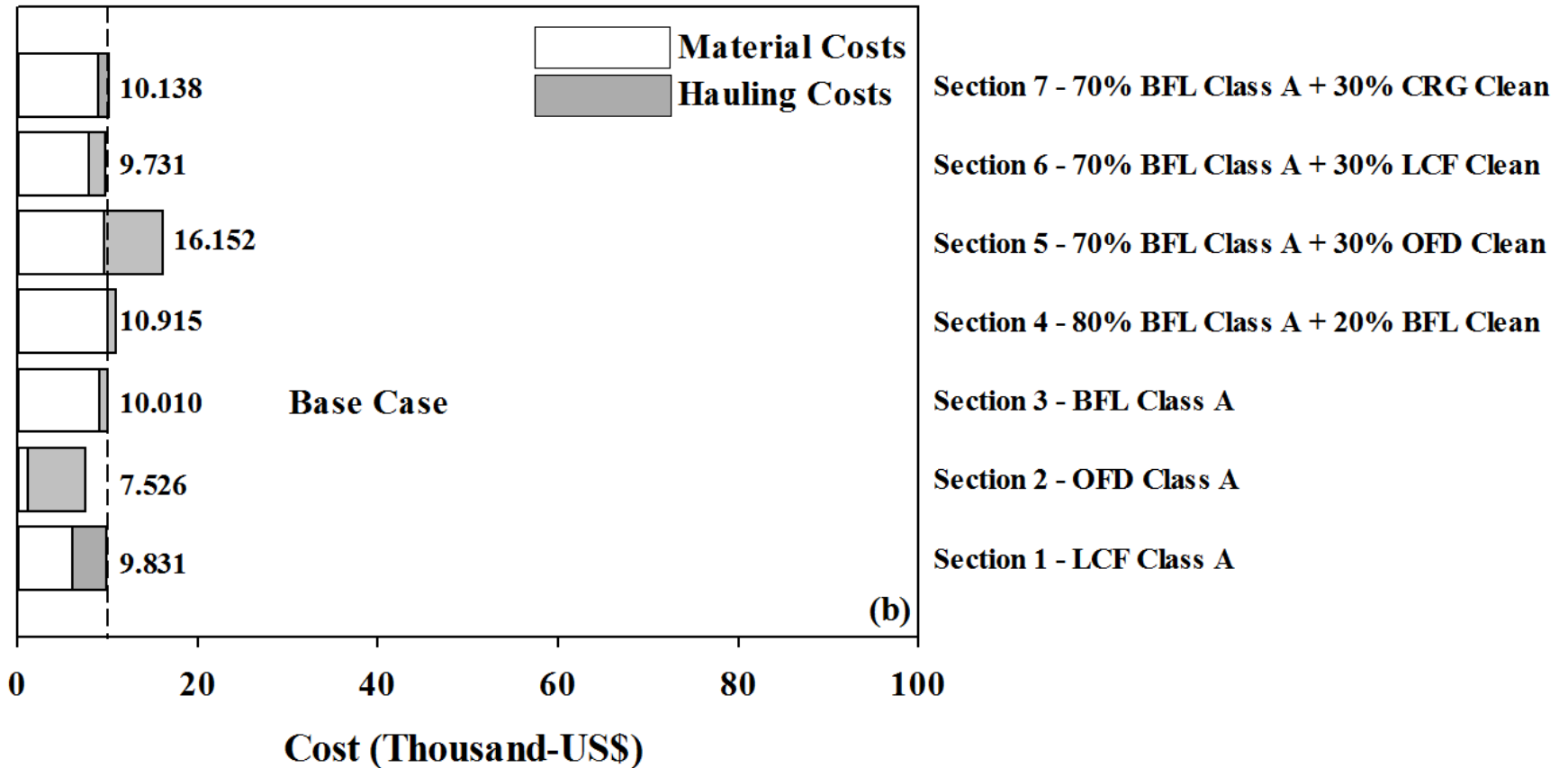


MAINTENANCE PROCEDURE



	Labor (hr)	Grader (hr)	Tandem Dump (hr)	Loader (hr)
LCF Class A	10	3	6	2
OFD Class A	7	2	4	1
BFL Class A – (Control Section)	10	3	6	2
80% BFL Class A + 20% BFL Clean	10	3	6	2
70% BFL Class A + 30% OFD Clean	10	3	6	2
70% BFL Class A + 30% LCF Clean	10	3	6	2
70% BFL Class A + 30% CRG Clean	10	3	6	2

MAINTENANCE COSTS



PERFORMANCE MEASURES

First Group

1. **Breakage**
2. **Fines Content**
3. **Gravel/Sand Ratio**

Second Group

1. **FWD**
2. **DCP**

Third Group

1. **Dustometer**
2. **IRI**

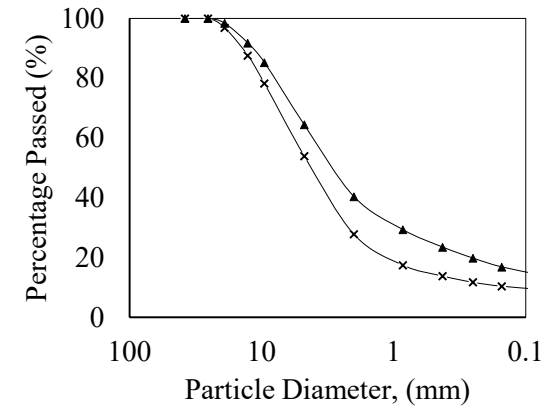
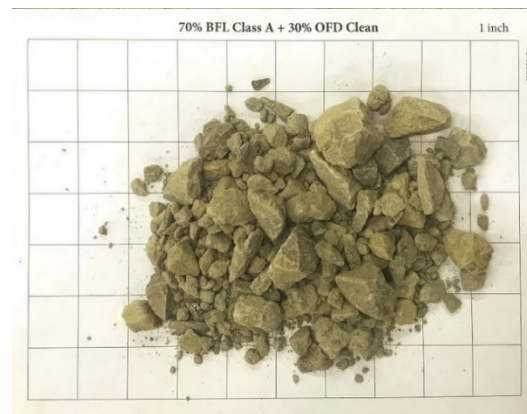
PERFORMANCE MEASURES: *First Group*

Material Loss

Fines Content

Gravel/Sand Ratio

Total Breakage



Hardin B., "Crushing of Soil Particles" - 1985

PERFORMANCE MEASURES: *Second Group*

Shear Strength (CBR)

DCP



Surface Elastic Modulus

FWD



PERFORMANCE MEASURES: *Third Group*

Dust Production

Dustometer



Surface Roughness

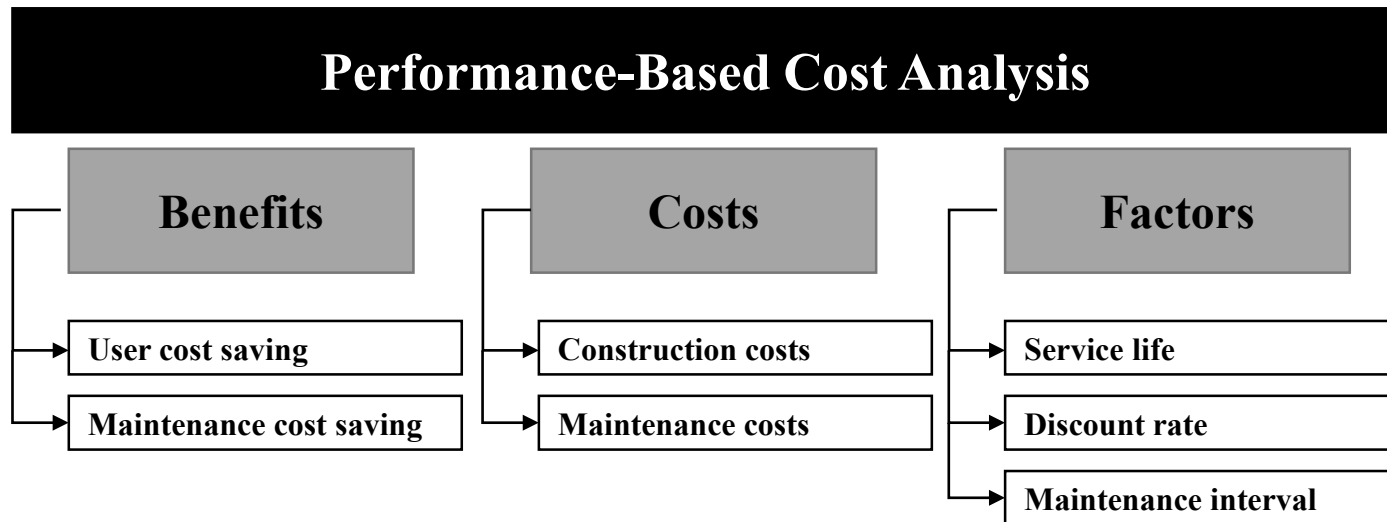
Roadroid



SCENARIO DEVELOPMENT: *Maintenance Intervals*

	Low Performance	Medium Performance	High Performance
Best Case	3 Years	4 Years	5 Years
Most Likely Case	2 Years	3 Years	4 Years
Worst Case	1 Year	2 Years	3 Years

ECONOMIC ANALYSIS ELEMENTS



COST ANALYSIS: *Summary*

Defining Benefits:

- **User Cost Saving**

$$\text{Travel delay cost} = (1 - T_t) \times P \times V_p + T_t \times V_t$$

- **Maintenance Cost Saving**

$$\text{Cost savings} = \text{New frequency} \times \text{New cost} - \text{Conventional frequency} \times \text{Conventional cost}$$

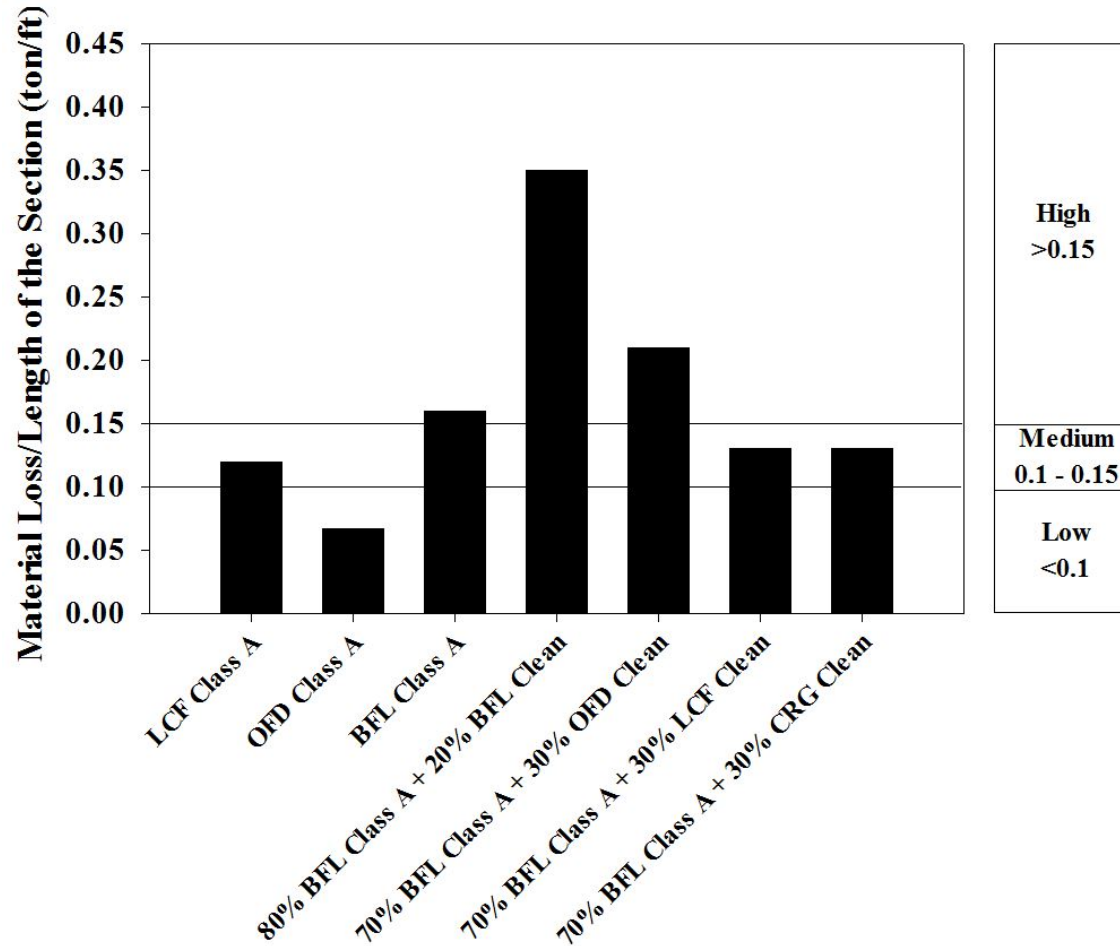
NPV = Construction Costs

$$+ \sum_{k=1}^n \text{Maintenance Cost}_k \left[\frac{1}{(1+i)^{n_k}} \right] - \text{Salvage Value} \left[\frac{1}{(1+i)^{n_k}} \right]$$

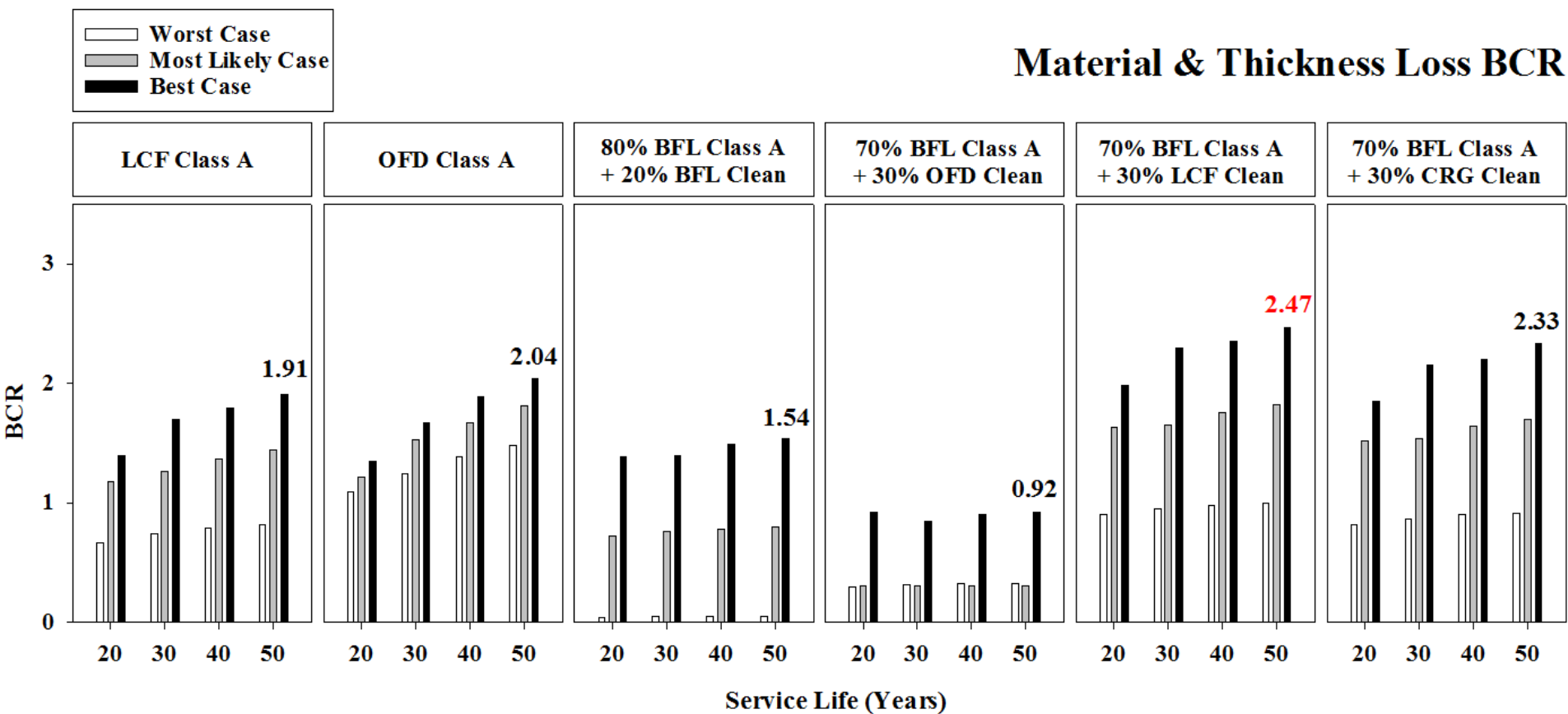
$$\text{Benefit Cost Ratio} = \frac{\text{NPV (Benefits)}}{\text{NPV (Costs)}}$$



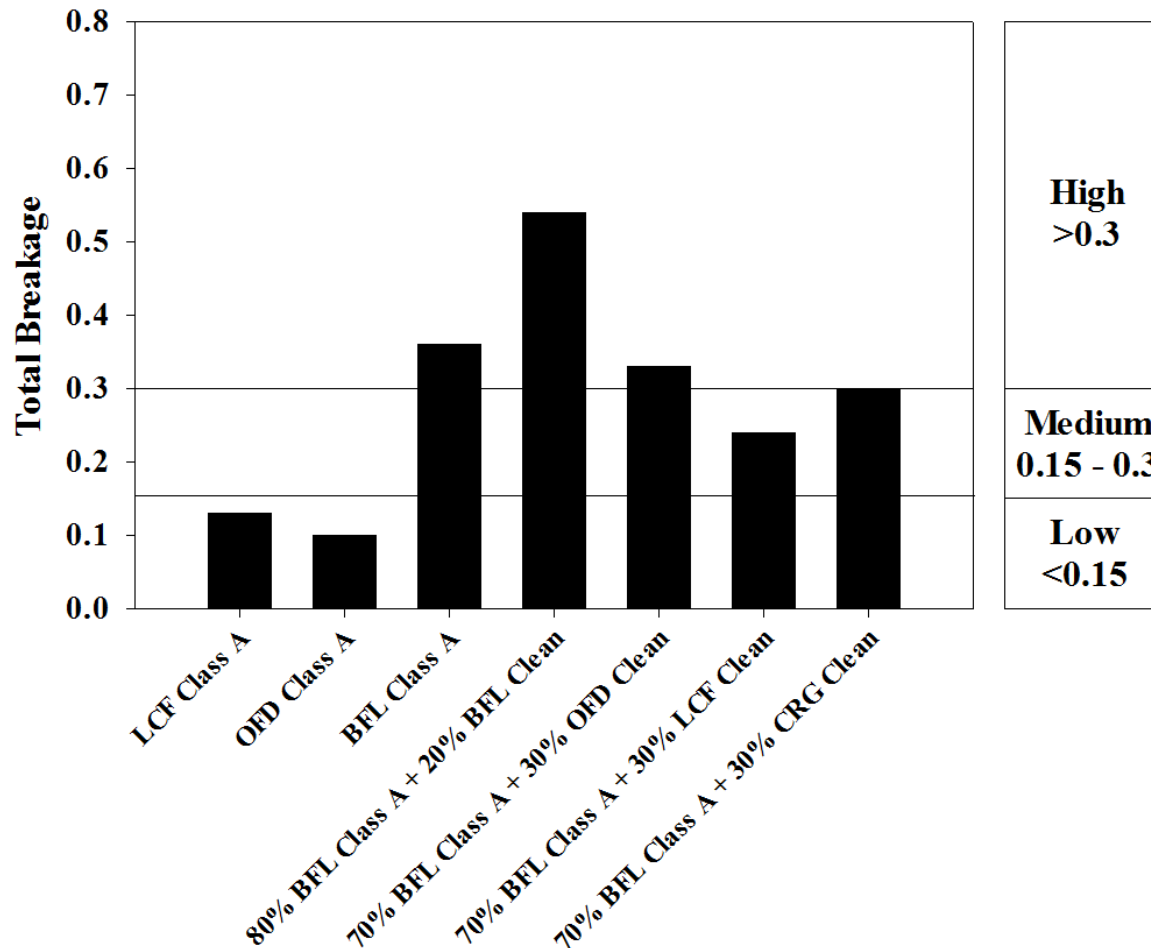
BCA: *Material Loss*



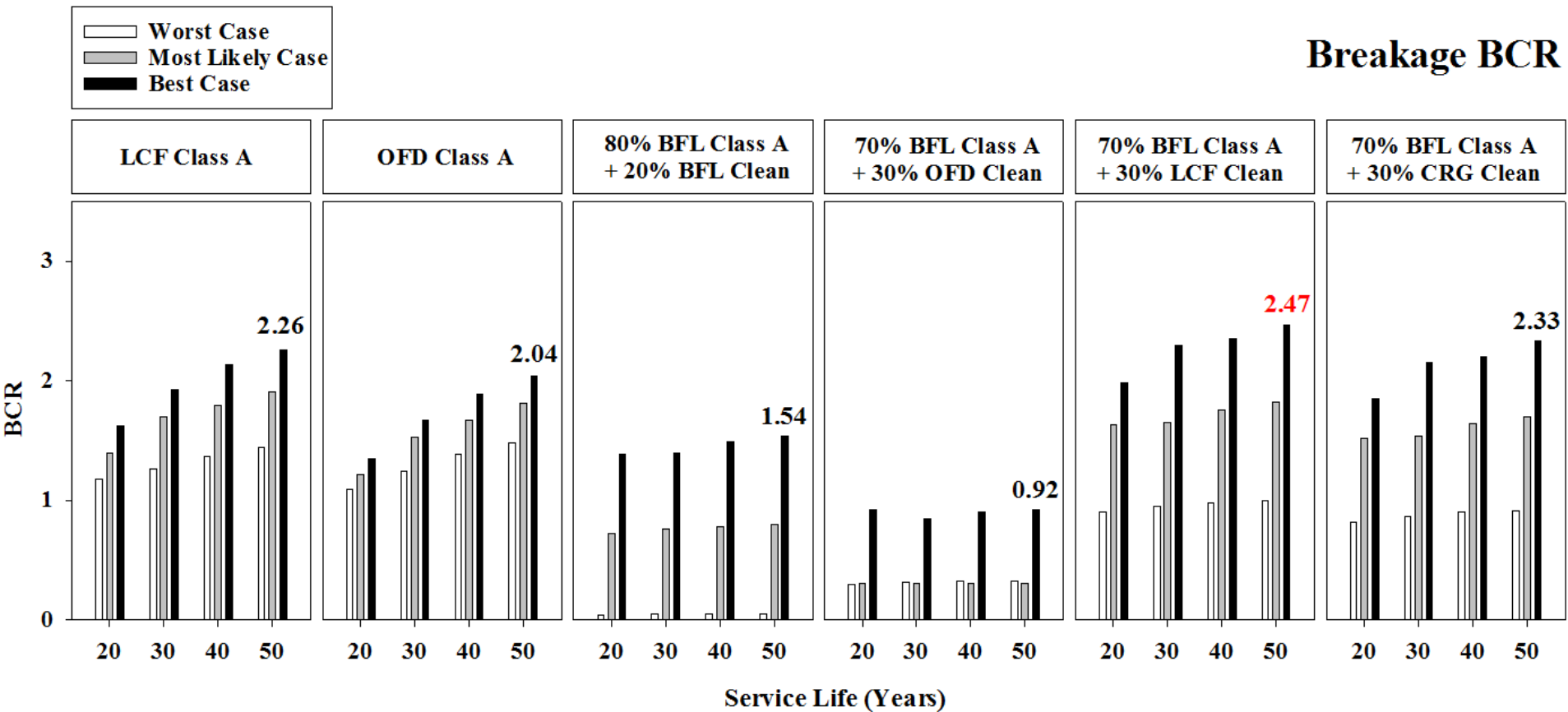
BCA: Material Loss



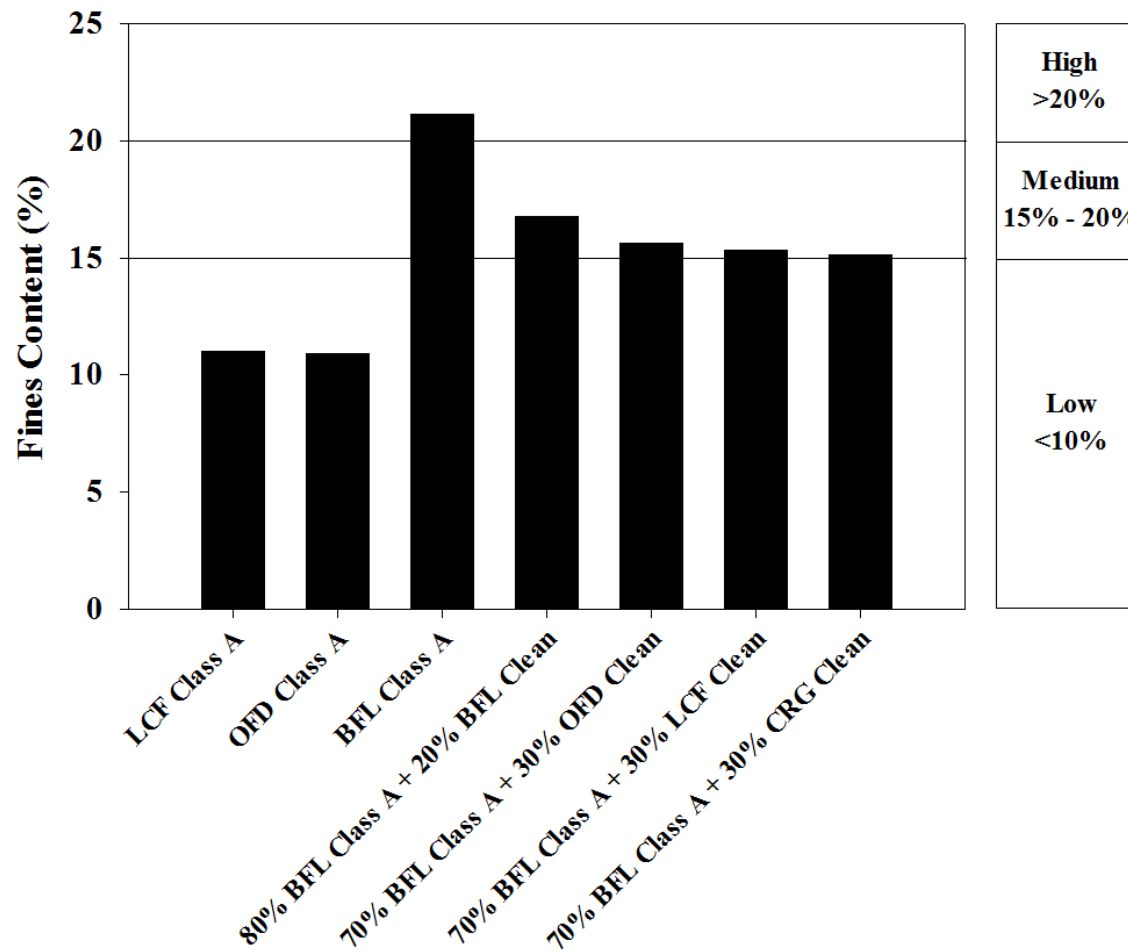
BCA (First Group): *Total Breakage*



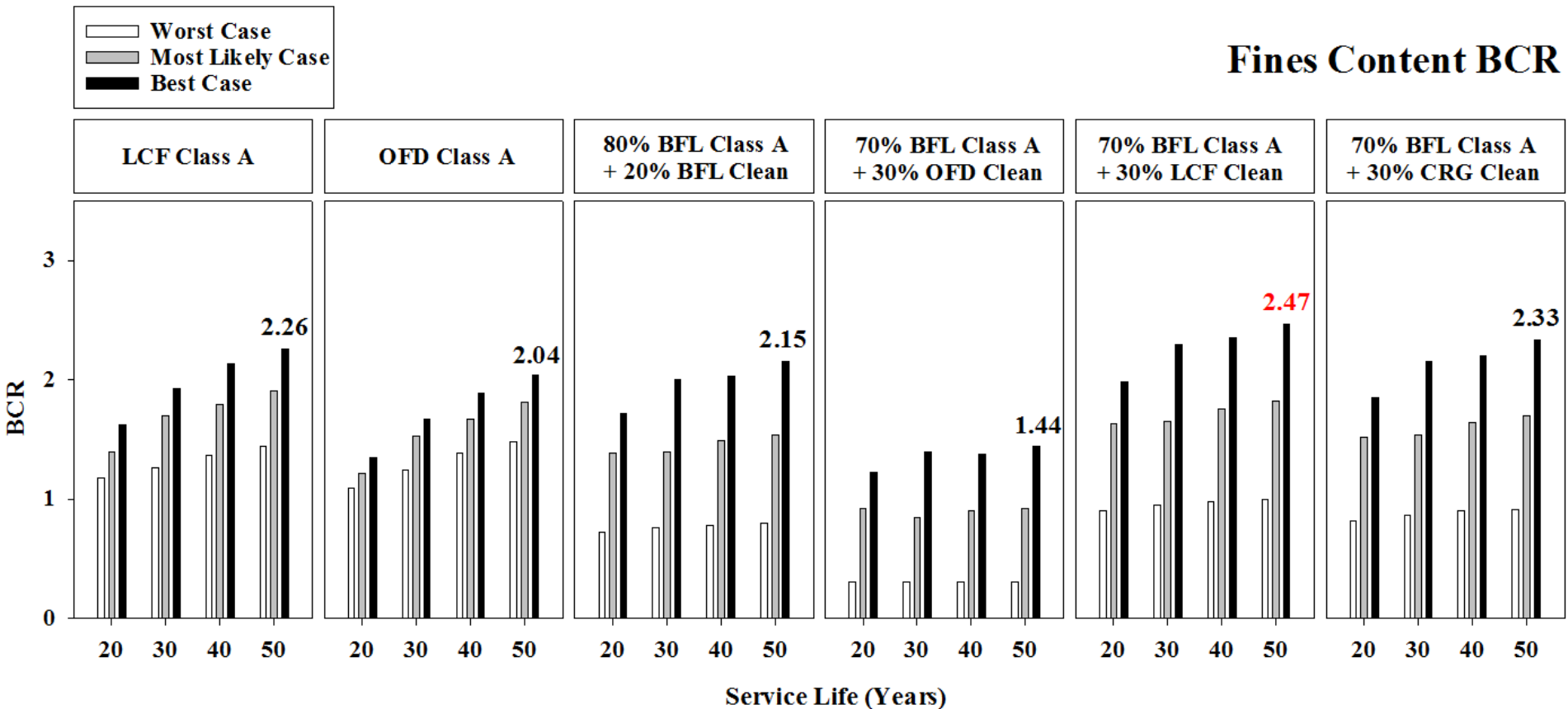
BCA (First Group): *Total Breakage*



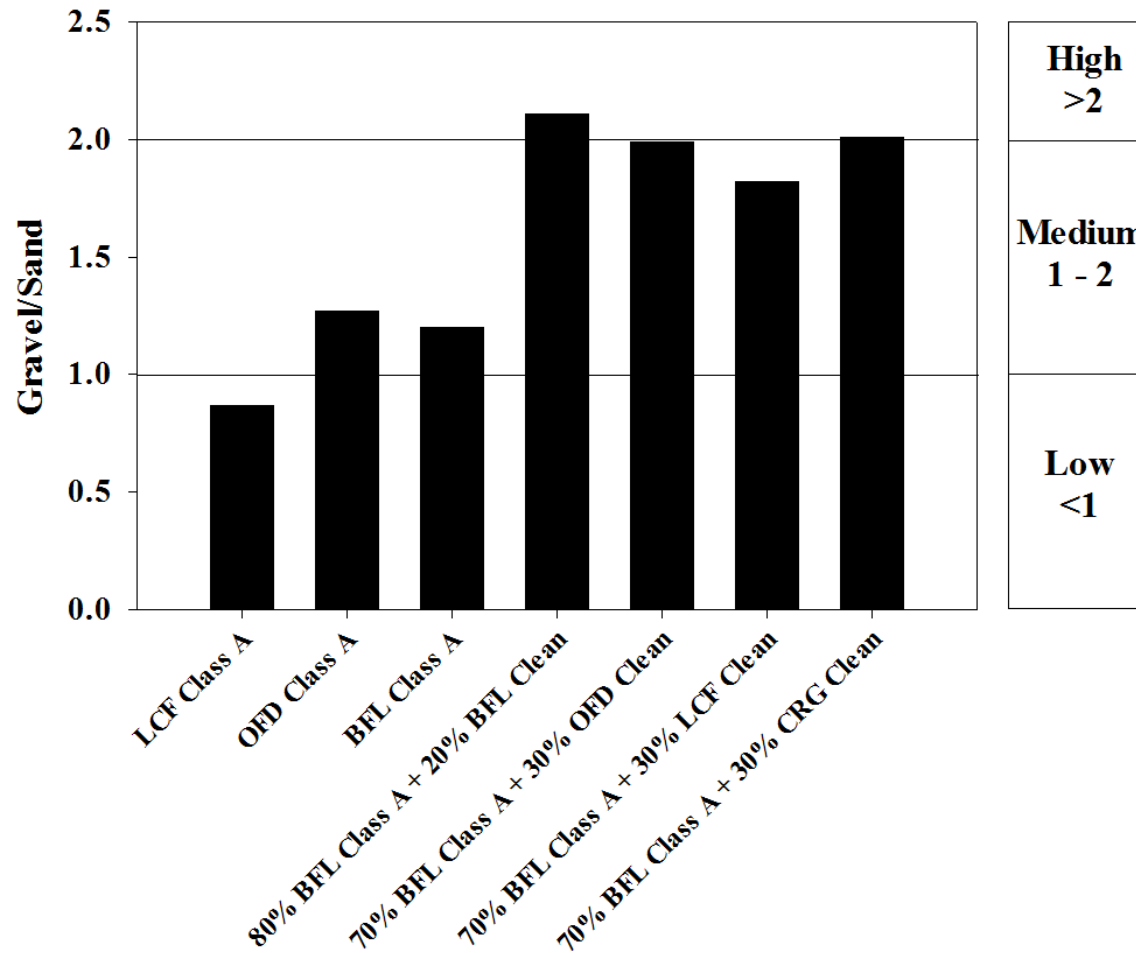
BCA (First Group): *Fines Content*



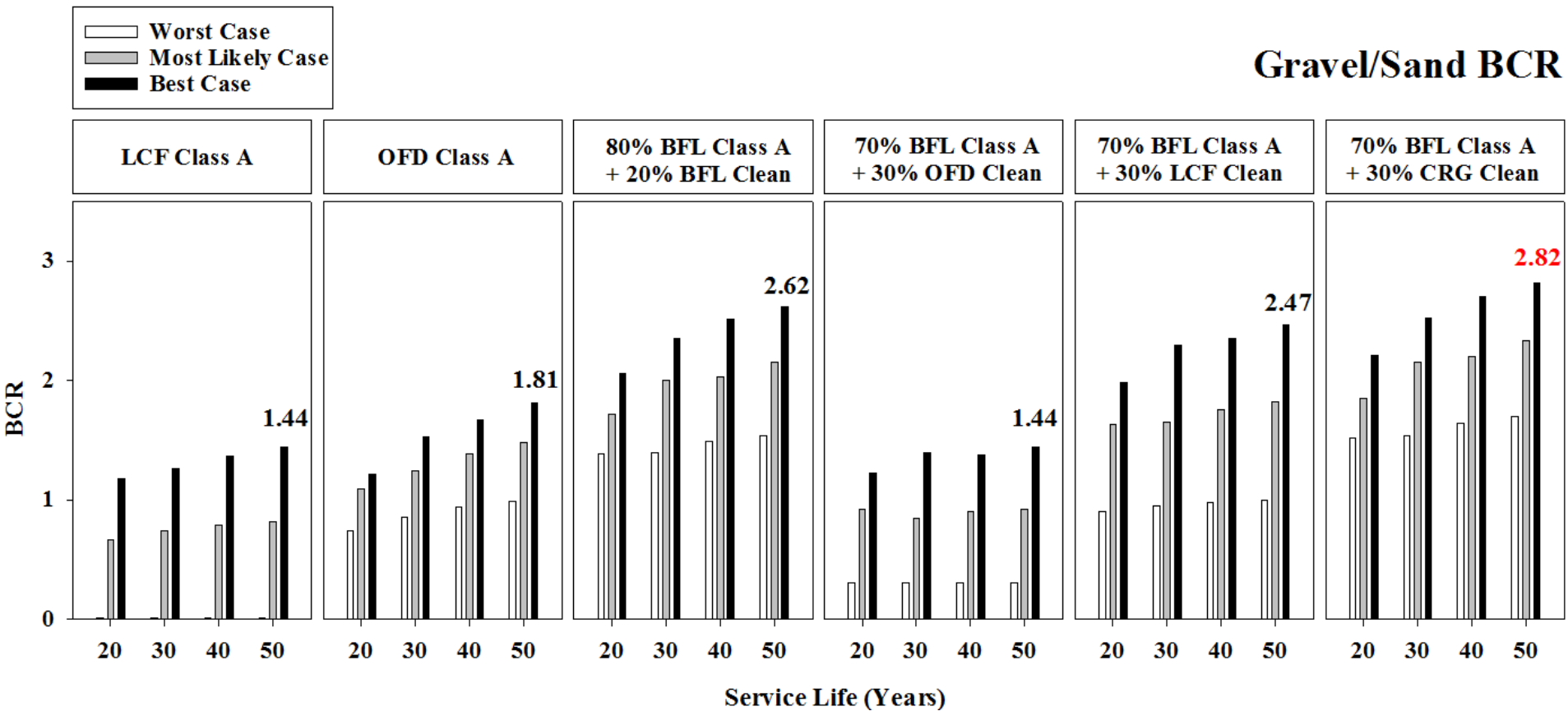
BCA (First Group): *Fines Content*



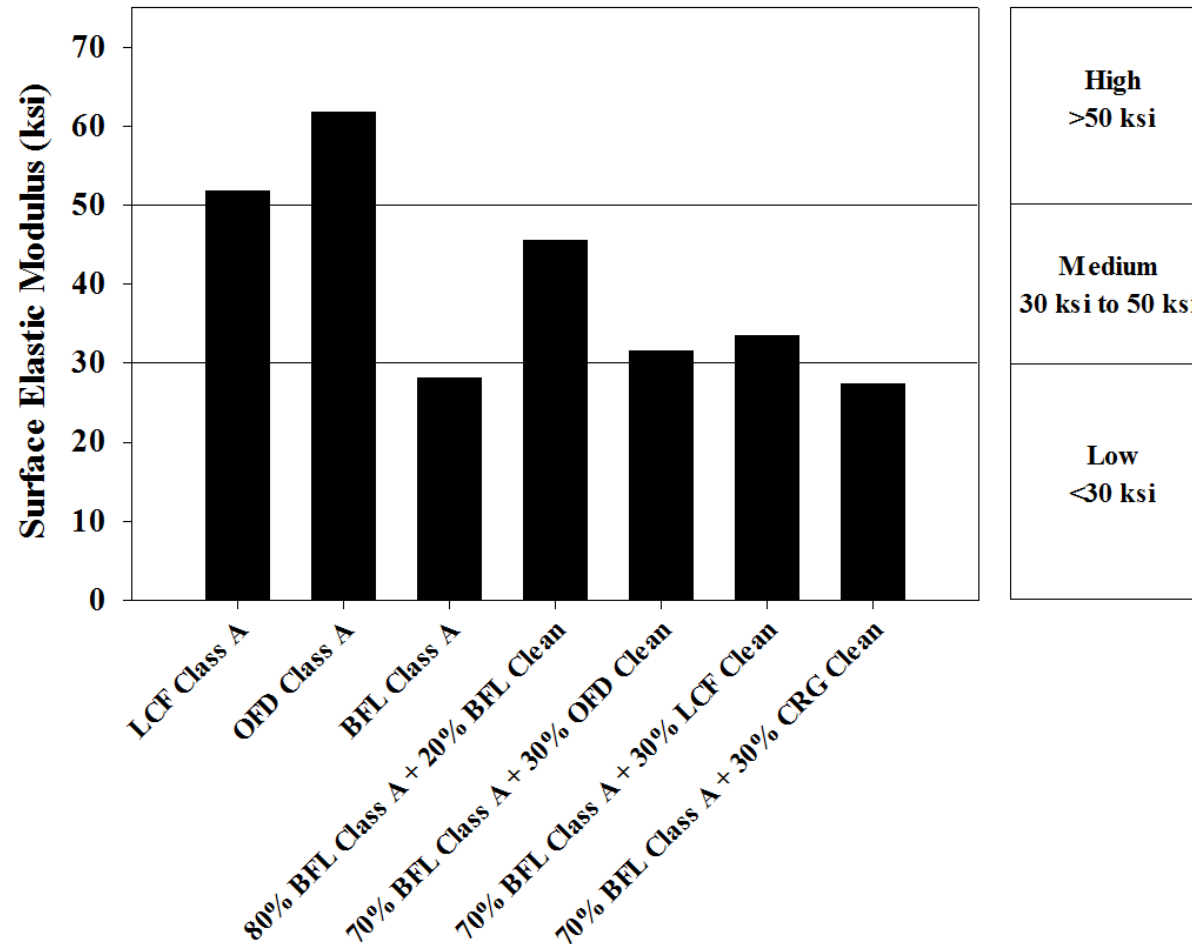
BCA (First Group): *Gravel/Sand Ratio*



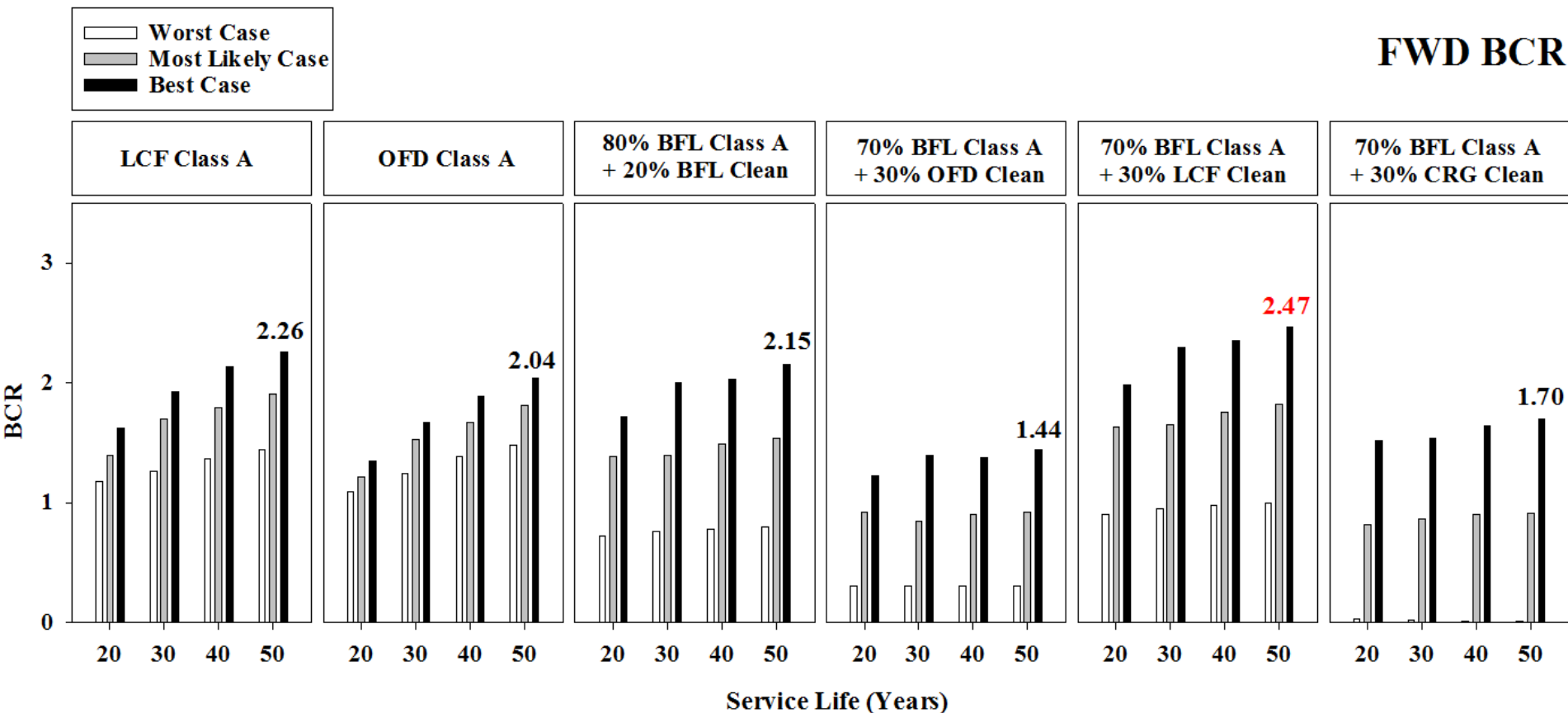
BCA (First Group): *Gravel/Sand Ratio*



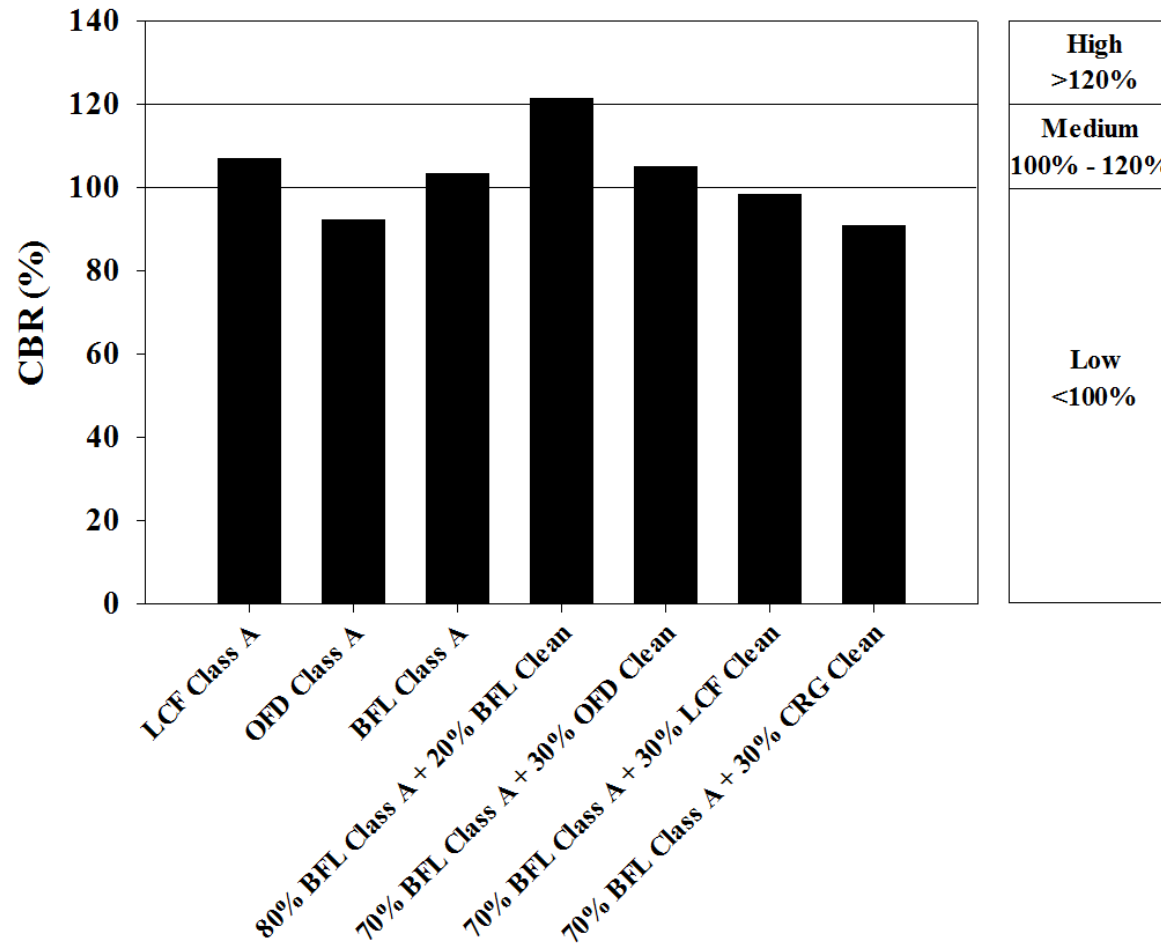
BCA (Second Group): *FWD*



BCA (Second Group): *FWD*

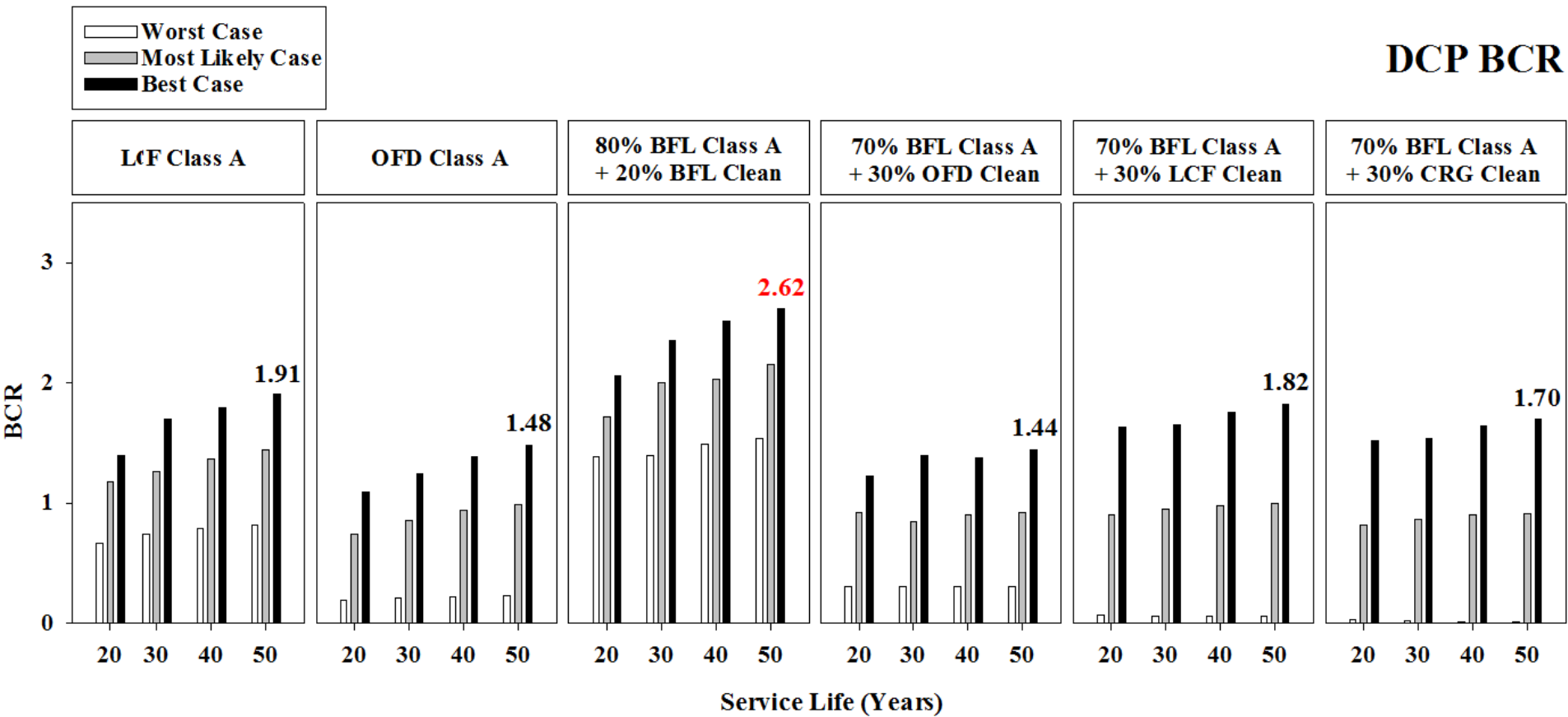


BCA (Second Group): *DCP*

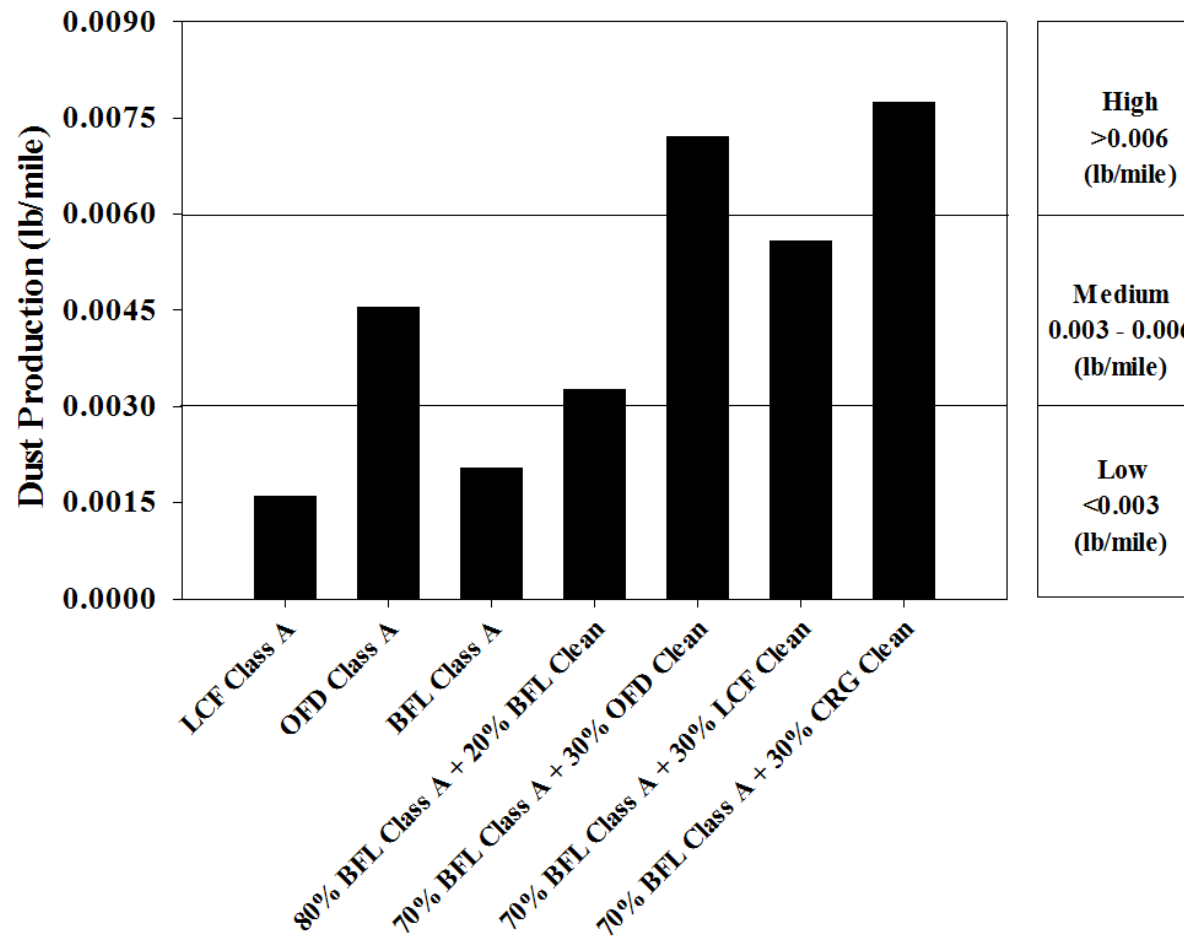


BCA (Second Group): *DCP*

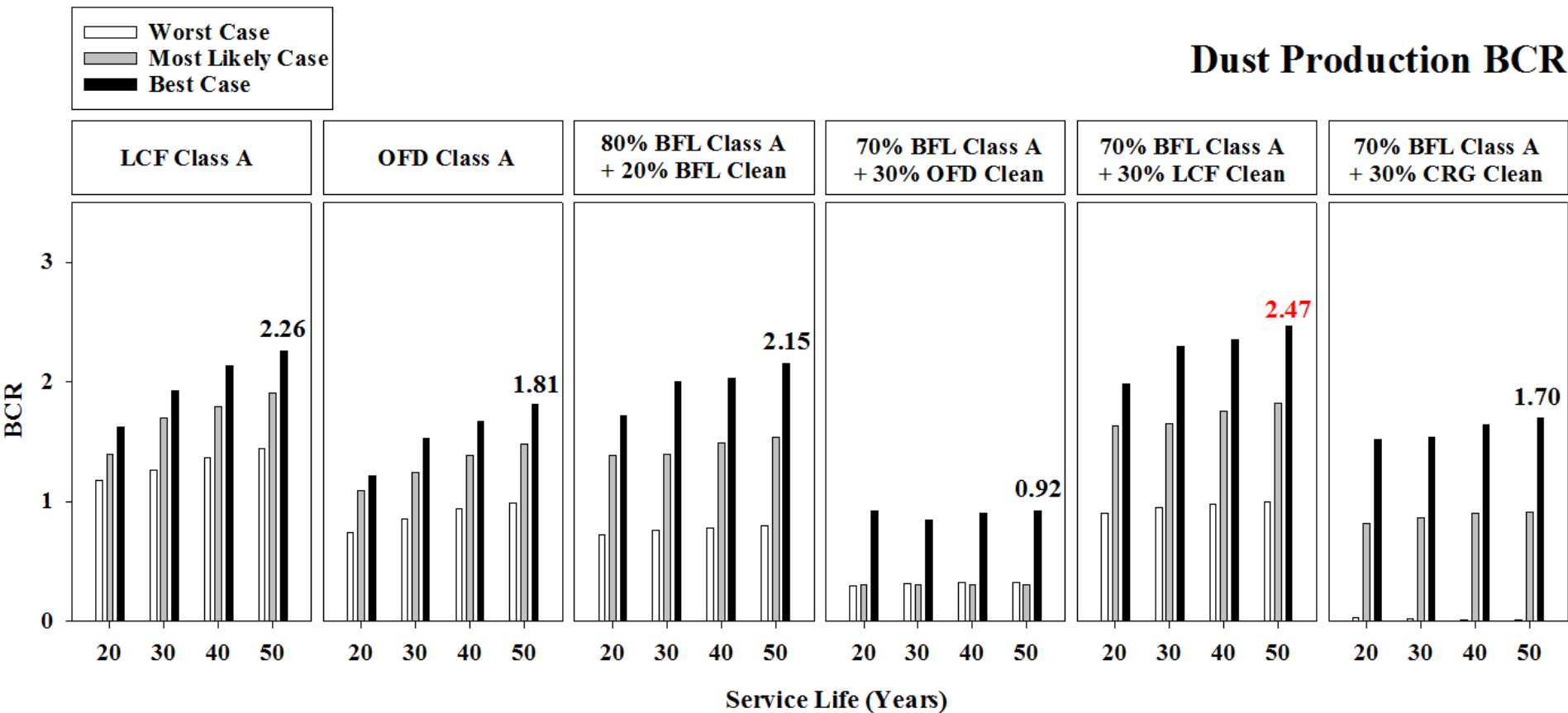
DCP BCR



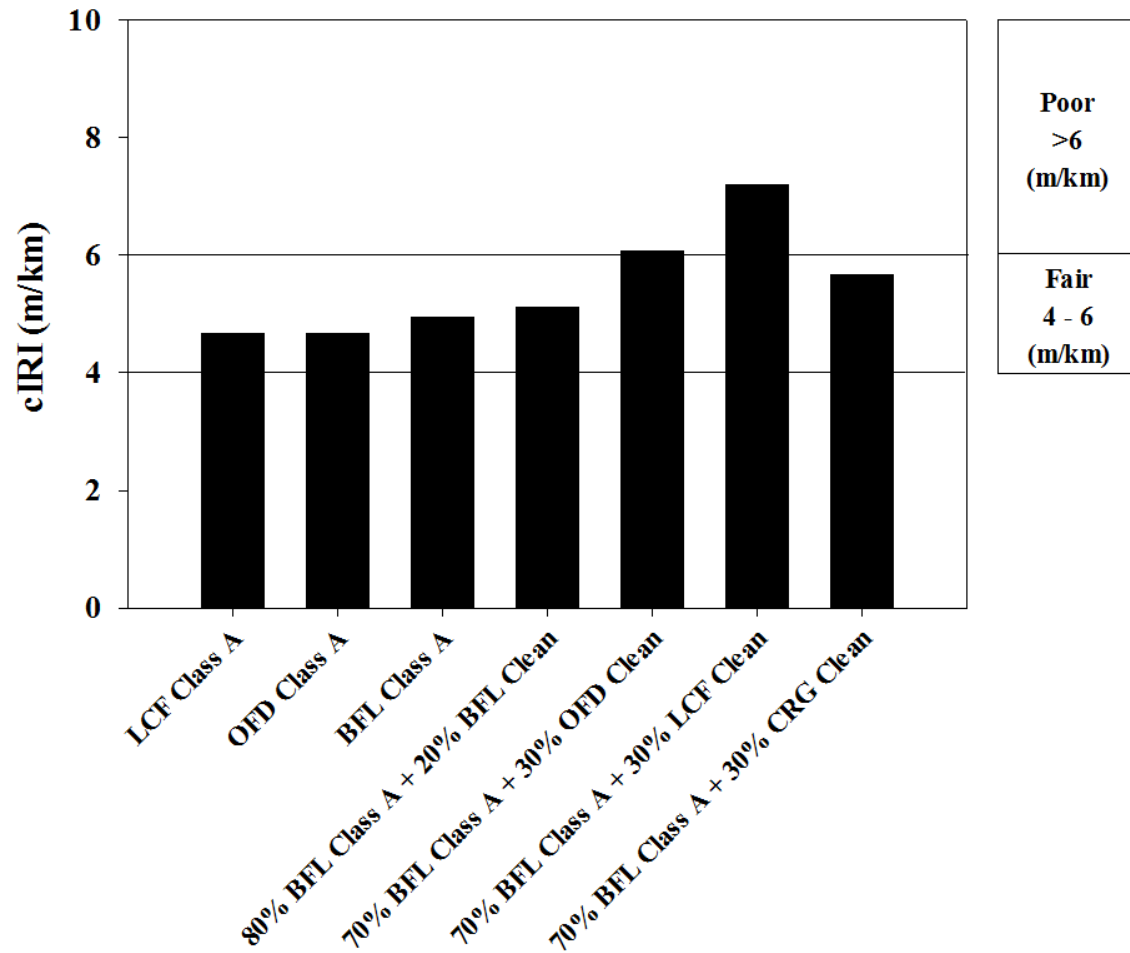
BCA (Third Group): *Dust Production*



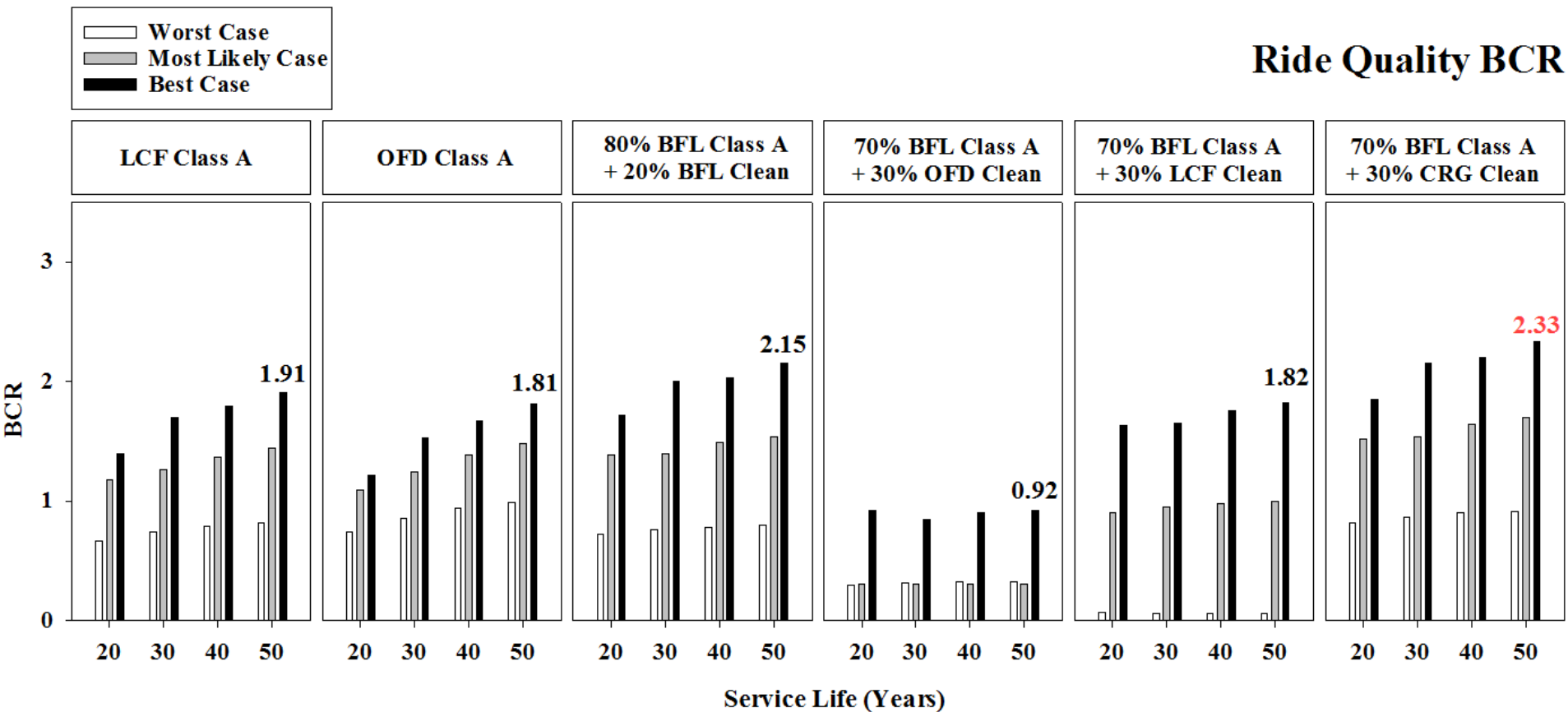
BCA (Second Group): *Dust Production*



BCA (Third Group): *Surface Roughness*

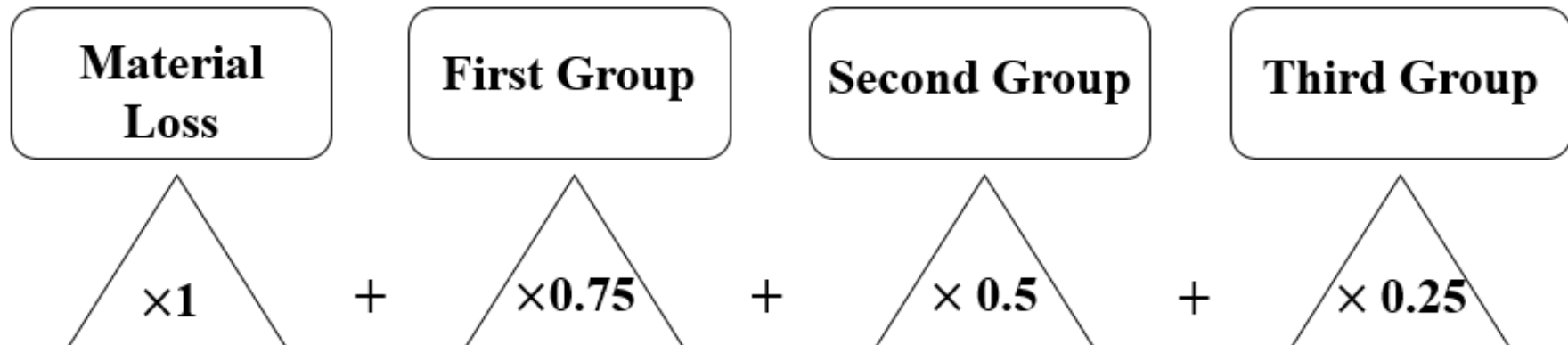


BCA (Second Group): *Surface Roughness*

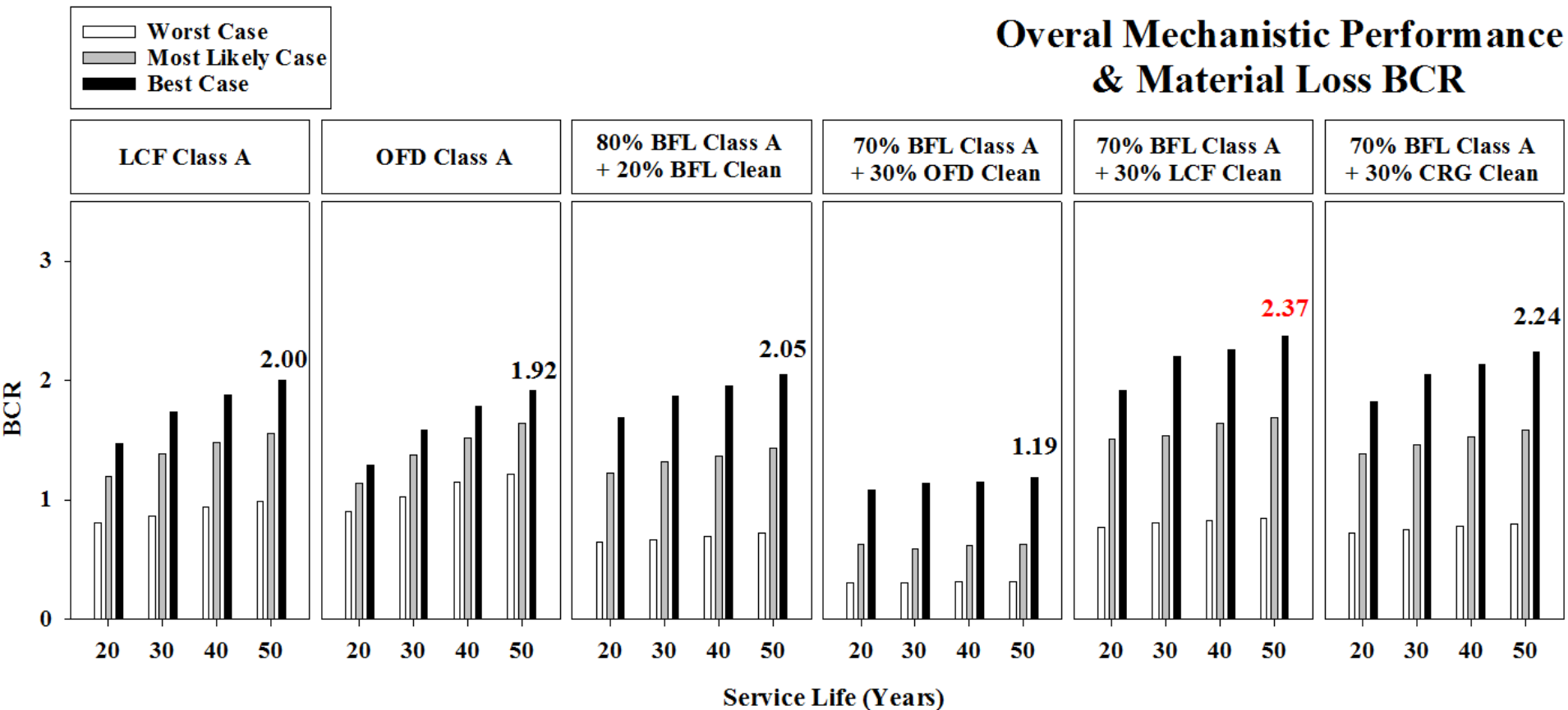


Performance – Based Economic Analysis

**Overall: Weighted average of mechanistic results
& Material/Thickness Loss**



Performance – Based Economic Analysis



CONCLUSIONS

OFD Class A

Highest Construction Costs

80% BFL Class A + 20% BFL Clean

Lowest Construction Costs

70% BFL Class A + 30% OFD Clean

Highest Maintenance Costs

OFD Class A

Lowest Maintenance Costs

CONCLUSIONS

**70% BFL Class A +
30% LCF Clean**



Fines Content

Dust Production

Total Breakage

FWD

Overall

Material Loss

**70% BFL Class A +
30% CRG Clean**



Gravel/Sand Ratio

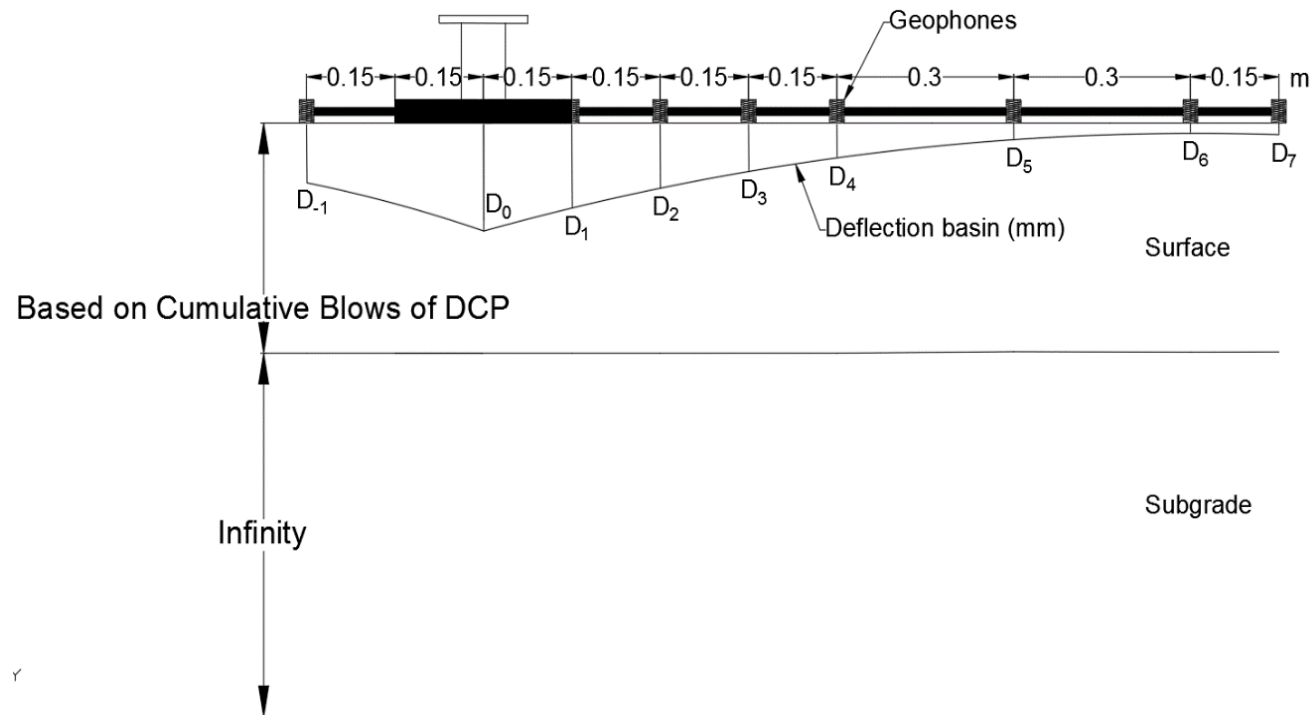
Ride Quality

Thank You!
QUESTIONS??



Appendix

FALLING WEIGHT DEFLECTOMETER



Parameters	FWD
Number of receivers	9
Receiver spacing (m)	0.15 to 0.31
Total length (m)	1.38
Distance from the source to the first receiver (m)	0

FALLING WEIGHT DEFLECTOMETER

Backcalculation Methods

- Boussinesq
- BAKFAA
- Modulus 7

Layer Numbers in Calculation

- Two Layers
- Three Layers

